ARCHAEOLOGICAL PALYNOLOGY IN THE UNITED STATES: A CRITIQUE

Vaughn M. Bryant, Jr., and Stephen A. Hall

Common problem areas in archaeological palynology include sampling, processing, counting, preservation, and interpretation. In this report, the authors present guidelines for researchers seeking pollen analyses, recommend the kinds of observations palynologists should make on their samples, and suggest ways of determining when samples should be considered invalid for paleoethnobotanical interpretations or paleoenvironmental reconstructions.

Las áreas problemáticas comunes en la palinología arqueológica incluyen muestreo, procesamiento, conteo, preservación, e interpretación. En este reporte, los autores presentan guías para investigadores en busca de análisis del polen. Se recomienda las clases de observaciones que los palinólogos deberían exponer en sus ejemplares y se sugieren maneras de determinar cuándo a estos ejemplares se los debería considerar nulos de interpretación paleoetnobotánica o de reconstrucciones paleo-ambientales.

Paul B. Sears was the first palynologist in North America to use pollen analytical data to resolve archaeological problems. In an early article, Sears (1932) demonstrated how fossil-pollen data could be used to reconstruct the paleoenvironment of late Holocene climates in areas of the eastern United States. He then suggested that fossil-pollen data confirmed the appearance of a humid period in the Ohio River valley around 3,000 years ago. This climatic change, Sears reasoned, would have been favorable enough for an eastward and northward expansion of agriculture into eastern North America from areas of the American Southwest. In another article, Sears (1937) explained how archaeological pollen data could be used to interpret cultural conditions at sites such as Spiro in Oklahoma. In later years, Sears went west and examined mainly nonarchaeological sediments in an attempt to establish a climatic sequence for the American Southwest (Clisby and Sears 1956; Sears and Clisby 1952).

It was not until the early 1960s that Martin (1963) and his students began systematic pollen studies of southwestern archaeological sites. Since that time, analysts have conducted hundreds of pollen studies of archaeological sites throughout the United States. Some of these have been published in books and journals, but most are being published in limited-edition contract-type reports that are rarely accessible to most researchers. Hall (1985) compiled a bibliography of all known fossil-pollen studies, including those from archaeological sites, for the American Southwest. Unfortunately, Hall's bibliography is already out-of-date, and similar bibliographies are yet to be compiled for other regions of the United States. Today, it is common to find pollen analyses being conducted on sediments in archaeological sites throughout all regions of North America, whereas, just a decade ago such studies were the exception, not the rule. This expanded interest in archaeological fossil-pollen studies has provided many students and professionals with new research opportunities, yet, it has also created some problems for archaeologists and palynologists alike.

The explosion of archaeological-pollen studies, created in part by more encompassing cultural-resource-management requirements, has resulted in a work "overload" for laboratories and facilities equipped to process and examine large numbers of archaeological pollen samples. A survey we conducted on pollen laboratories revealed a per-sample cost ranging from $85 to more than $150 for a complete analysis with the average cost being about $125. The per sample cost for processing

Vaughn M. Bryant, Jr., Department of Anthropology, Texas A&M University, College Station, TX 77843–4352
Stephen A. Hall, Department of Geography, The University of Texas at Austin, Austin, TX 78712–1098

American Antiquity, 58(2), 1993, pp. 277–286.

pollen samples where the only information needed is a quick examination of the residue to determine whether or not fossil pollen is actually present, ranged from $35 to nearly double that price at some labs. In addition, the completion time for fossil-pollen processing, analysis, and delivery of a final report also varied from a few weeks to as much as six months. Some laboratories also indicated that in emergency cases, when the need for an immediate analysis was critical, they might be able to meet a short deadline, but the per-sample price would be considerably higher.

Some of the laboratories we checked also reported that during the past year there were times when they were unable to accept new contracts for analyses because they already had too many project commitments. In those instances, laboratory personnel usually suggested that the caller contact one of the other pollen laboratories for help. Although we cannot be certain, we believe that the existing pollen laboratories in the United States are currently barely able to satisfy the total demand for needed archaeological fossil-pollen analyses. We also heard many lab personnel say that one of their biggest problems was a "feast-or-famine" situation where their laboratory either did not have enough samples to stay busy, or had requests that far exceeded their capacity to complete the needed analyses within fixed deadlines.

This report is our attempt to offer a few suggestions that we hope will be helpful to future researchers seeking archaeological pollen analyses.

POLLEN SAMPLING

There are a number of published sources that can provide archaeologists with suggestions on how to collect pollen samples, how to determine the number of samples to be collected, how to gauge the quantity of material to collect, and how to decide on the types of deposits to sample (Bryant and Holloway 1983; Dimbleby 1985; Pearsall 1989). Even so, a few of the most important points need restating.

Many types of pollen grains become airborne and settle to the surface. This process is called the "pollen rain." Even in winter, when few plants are pollinating, deposited pollen can become recycled into the atmosphere with dust particles and will later fall to the surface in new locations. Therefore, the first, and most important rule, for pollen sampling is to use clean sampling implements, clean pollen-free containers (like heavy-duty zip-lock bags), and collect samples from cleaned surfaces of excavation profiles. Cleaning a profile with a pick or trowel immediately before sampling is mandatory.

When we are asked about the number of pollen samples one should collect, we respond by saying that it is better to collect too many samples than not enough. Once areas of a site are disturbed and removed during excavations, it is impossible to go back and collect pollen samples that "should" have been taken during the excavation. Likewise, it is also helpful if archaeologists can collect control samples. These would be collected from surface locations near where archaeological sites will be sampled. Control samples are helpful because they reveal the types and percentages of modern pollen present in the sampling area. When this information is keyed into a study of the contemporary vegetation, it helps the palynologist determine which pollen types might be over, or under, represented in the fossil record of that region.

Control samples should be collected using the "pinch" method outlined by Adams and Mehringer (1975). The number of control samples one should collect will vary depending on how extensive the fossil testing will be and how many different archaeological site locations will be tested for fossil pollen. As a general rule, we suggest collecting at least one control sample in each of the cardinal directions approximately 200 m away from an archaeological site that is being tested. As with fossil samples, it is always better to collect too many control samples than not enough.

An example of correct pollen sampling was exemplified by the excavations at Antelope House Pueblo by archaeologist Don Morris (1986). Approximately 1,000 pollen samples were collected during the excavation of that site. Later, only one-third of the 1,000 pollen samples were ever processed. However, the archaeologist had collected samples from every important location at the site. This made later pollen analyses precise and meaningful (Bryant and Morris 1986; Bryant and Weir 1986; Williams-Dean 1986).

Most of the pollen laboratories we surveyed prefer to process between 20 and 50 g or 20–50 cm^3 of soil from each archaeological pollen sample, but there are exceptions. Sometimes the sediment inside a sealed container or ceramic bowl may not contain large quantities of soil. Pollen washes of manos and metates also produce only a few grams of soil, and sometimes the scrapings from pueblo floor surfaces may consist of less than 10 g of sediment. There are other exceptions as well. These include pollen samples extracted from coprolites, soils, or from residues that might be adhering to the surface of stone tools, and dirt trapped in the weave of ancient matting and baskets. One of the best policies is to collect approximately one large handful of soil per pollen sample whenever possible. This amount will permit a palynologist to process several different 20–50-g samples, if needed, and will leave sufficient soil to permit other types of analyses.

It is difficult for us to provide an all encompassing guide recommending "what" to sample. Archaeological sites vary in their contents and complexity and no one sampling strategy will work for all sites. Perhaps the most important question that any archaeologist should ask is, "What types of information do I hope fossil-pollen data will provide?" If one is searching for possible differences in the economic use of plants, or changes in the use of plant foods through time, then collecting pollen samples from individual strata or from fixed intervals on the face of exposed profiles is recommended. Collecting pollen samples from features is also advisable. The only exception would be samples from the centers of ash-filled hearths because fires usually oxidize pollen.

Burials are sometimes associated with graveside rituals involving pollen, flowers, or other plant parts (Bryant and Morris 1986). Collecting pollen samples from soils in contact with the underside of skeletons and from areas inside the chest and pelvic cavity may provide valuable evidence of cultural events. Floor surfaces often trap pollen that may have been brought into a room with plants that were prepared as food. Therefore, floor scrapings might assist in assigning a functional use to rooms in structures such as pueblos based on their fossil-pollen contents (Hill and Hevly 1968). Dirt in contact with the inside bottom portion of ceramic vessels may contain pollen from materials once stored in the vessels. Also, dirt trapped in the textured surface of grinding stones often has traces of pollen from the plants that were once ground on those surfaces (Bryant and Morris 1986). Dirt trapped inbetween the weave of baskets may reveal which plants were stored in the baskets, pollen adhering to residue on stone tools may indicate the plants that were once cut by that tool, and the pollen trapped in human coprolites can reveal many aspects about prehistoric diets (Sobolik 1988). And the list goes on.

One final word of caution is recommended. If samples are collected from moist soils in archaeological sites, then steps need to be taken to ensure that bacteria and fungi do not attack and destroy the remaining preserved pollen. The easiest way to prevent damage is to freeze soil samples until they can be processed in a laboratory. Freezing will not damage pollen and it will prevent the growth of microbes. If freezing samples is not possible, several capfuls of rubbing alcohol poured into the soil of a sample that is then sealed in a zip-lock bag will achieve the same result.

POLLEN PROCESSING

Palynology is an apprenticeship science where a novice works with and learns from a skilled professional until both are convinced that the novice knows and understands the essential points on how to extract fossil pollen. Although there are a number of textbooks (Faegri et al. 1989; Moore et al. 1991; Traverse 1989), book chapters (Gray 1961), and individual articles (Bond 1964; Lennie 1968; Phipps and Playford 1984) that discuss the benefits and pitfalls of extracting fossil pollen from different types of soil matrices, there are many shortcuts and variations in use that are not published. Often, laboratory-processing techniques can be taught to a skilled novice rather quickly.

If there is a concern that certain extraction techniques might be destroying fossil pollen, then we recommend conducting a test. One way a test can be conducted is to begin with two or three subsamples of the same sediment and then process each subsample using a different extraction procedure. A pollen analysis of each of the resulting residues should produce similar pollen counts. If they do not, then at least one of the extraction procedures might be suspect. The second method of checking procedures would be to add some type of exotic pollen to a soil sample prior to beginning the extraction process. Once processing is completed, if the exotic pollen type is still present, then the procedure is probably safe. The choice of an exotic pollen type should focus on a type not normally found in the flora of the region where a fossil soil sample was collected. For example, in soil samples from Canadian sites the pollen of tropical plants, like gum trees (*Eucalyptus*), would be an ideal choice as an exotic type. For soils from arid regions, like the American Southwest, pollen from a northern plant (i.e., eastern hemlock [*Tsuga canadensis*]), or the spores from the mesophytic club moss (*Lycopodium*), would be ideal.

One of the recent advancements in archaeological pollen processing has been the regular use of tracers to evaluate the concentration of fossil pollen per unit volume, or unit weight, of a sample. The tracer is generally a pollen or spore type not typically found in most North American archaeological sites. Two of the most common ones in use are *Eucalyptus* pollen and *Lycopodium* spores (Stockmarr 1971).

A known quantity of tracer pollen, or spores, is added to a known volume, or weight, of sample before the extraction procedure begins. After completing the extraction, and during the analysis phase, the ratio of fossil-pollen grains counted, to the number of tracer grains counted (during a normal pollen count to a fixed sum of 200–300 fossil grains), allows the analyst to calculate the fossil-pollen concentration. That information can then be converted to a ratio representing the number of preserved pollen grains per unit of weight, or volume, of sample.

Knowing the fossil-pollen concentration of an archaeological deposit can provide valuable clues about the net rate of sediment deposition, whether or not certain pollen types are present in unusually high numbers, and the rate of fossil-pollen destruction. If, for example, the annual amount of pollen being deposited on the surface of an archaeological site remains fairly constant over a long period of time, but the cultural activities of the site's occupants create a deposit of 3 cm of sediment matrix per decade, then the pollen concentration for the 3 cm of sediment would be quite low per unit weight or volume of soil. If the reverse were true, and in the absence of human occupation for 100 years only 3 cm of silt were deposited, then the concentration of fossil pollen would be approximately 10 times as great in those sediments per unit of soil, provided no pollen was lost to degradation.

Unusually high concentrations of a single pollen type in the soils of an archaeological site might reflect the specific economic use of a plant. If an area in a site had been used to thresh a cereal grain (i.e., wheat, barley), or an area was used to strip the husks from maize cobs, or used to strip and process large quantities of goosefoot seeds, then the soils in those areas should contain unusually high concentrations of economic pollen.

Pollen-concentration studies can also be used as a general guide for determining the amount of pollen that may have been destroyed during the postdepositional period of a deposit. Postdepositional processes, such as pedogenesis, mechanical destruction, chemical oxidation, and microbial activity, may dramatically reduce the amount of pollen in a deposit. Based on decades of experience, we have concluded that pollen concentrations in soils collected from open sites, or from rockshelter sediments, which do not contain at least 1,000 grains per g (dry weight of sample), or 2,500–3,000 pollen grains per cc of sediment, generally characterize samples that have undergone severe pollen loss through postdepositional alteration. And, we believe that in most cases, samples containing pollen levels this low should not be used as the basis for reliable types of interpretative information. However, there are exceptions.

Deposits collected from the soils of sites located inside deep caves, floor scrapings from interior rooms in pueblo structures, and some sites located in the arctic, where airborne pollen deposition is minimal, generally will not contain high concentrations of fossil pollen even under ideal situations. Thus, until sufficient testing can be performed to determine what the "normal" pollen concentrations should be in these types of cultural deposits, one should not discount these pollen records even when fossil-pollen concentrations fall below the minimal numbers mentioned above.

Some pollen analysts, such as Horowitz et al. (1981), have suggested that when pollen concentrations in sediments are low, one should simply process larger volumes of sediments to obtain more pollen. While this might be justified in a few limited situations, it is not justified for most open sites or rockshelter deposits. When a low concentration of fossil pollen is due to a high degree of postdepositional pollen deterioration and destruction, then the resulting pollen assemblage will be just as unreliable whether a large or small amount of the sample is processed.

POLLEN COUNTING

For years, analysts have debated the number of pollen grains one should count per sample. Generally, for most archaeological sediments a 200–300-grain pollen count is regarded as sufficient to document the occurrence and proportions of fossil pollen (Barkley 1934; Martin 1963). However, there are exceptions. Sometimes pollen washes of manos and metates will not yield sufficient fossil pollen for a 200–300-grain count. Also, the number of pollen grains recovered from the dried residues adhering to lithic tools may be very few, if present at all (Shafer and Holloway 1979).

Clary (1989) was the first to develop the concept of large-fraction analysis as it applies to the recovery and identification of specific types of economic pollen in archaeological sites. Since the 1960s, palynologists have known that the pollen of cultivars, such as squash (*Cucurbita*), cotton (*Gossypium*), and maize (*Zea*), and the pollen from other types of economically important plants such as prickly pear cactus (*Opuntia*), were rarely found in the sediments of sites where these plants were probably used. Often, during normal pollen counts of southwestern U.S. soils collected from sites where a farming economy was suspected, none, or maybe only a single cultigen pollen grain was found.

Because pollen counting is time consuming and much of it is now being done on a contract basis, the additional time needed to count extra microscope slides containing pollen residues of the same sample is often deemed too expensive. For example, it may take over one hour for a skilled pollen analyst to obtain a 200–300-grain count from a single archaeological sample. It may take that same person nearly half a day to count an additional 500–1,000+ pollen grains from that same sample while searching for possible cultigen pollen.

In an effort to maintain statistically valid controls, and yet examine a larger portion of an archaeological pollen sample, Clary (1989) developed a technique where she first obtained a standard pollen count (200–300 grains) and then sifted a large-fraction of the remaining pollen residue through a screen with tiny openings of 40 μm. This technique removed most of the small-grained fossil-pollen types and left only the larger pollen types, most of which were those of cultigens. This large-fraction extraction technique enabled Clary to develop a quantitative method for reporting normal pollen-concentration values from an initial 200–300-grain count, and then reporting the large-fraction concentration values for cultigens and cactus. Since Clary's original work in 1989, Dean (1991) and Gish (1993) have introduced their own variations of the large-fraction-analysis technique.

POLLEN PRESERVATION

The fossil pollen recovered from some North American archaeological sites is well preserved. However, it has been our experience, and the experience of others, that pollen in the sediments of many archaeological sites is poorly preserved (Bryant 1969; Hall 1981, 1991; King et al. 1975). Trying to identify broken, folded, crumpled, and degraded pollen grains in archaeological samples is often a difficult task. Some grains are so badly deteriorated that there is an uncertainty as to their proper taxonomic identity. When identification of these types of grains is not possible, we call them "indeterminable." As a general guide, when a sample's number of indeterminable grains exceeds 50 percent of the total count, the reliability of the pollen assemblage should be sharply questioned, especially if the sample's pollen concentration also falls below 1,000 grains/g or 2,500 grains/cc of sediment. In reference to archaeological samples, other palynologists, like Dean (1991:8), state, "I usually consider unidentifiables above, say, 10% to indicate increasingly poor preservation generally, but specific research questions will determine whether *very* poorly preserved pollen samples retain analytical utility."

The variables affecting the preservation, or destruction, of pollen grains are poorly understood even though a number of researchers have examined the issue (Bryant 1988; Bryant and Schoenwetter

1987; Bryant et al. 1993; Dimbleby 1957, 1985; Hall 1981, 1991; Holloway 1981, 1989; King et al. 1975). The causes of pollen destruction in archaeological sites are not well understood, yet some factors that contribute to pollen loss have been identified. Rapid changes in atmospheric-moisture levels can cause some pollen types to rupture and fragment, especially grains like those of cypress (*Taxodium*), juniper (*Juniperus*), and cedar (*Thuja*) (Duhoux 1982). The chemical composition of the pollen wall also seems to play an important role in determining which pollen grains will remain preserved and which ones will not. A 20-year experimental study conducted by Havinga (1964, 1984) found that the ratio of sporopollenin (a carotinoid-type compound) to cellulose in the wall of a pollen grain affects its susceptibility to destruction and that pollen grains having high amounts of sporopollenin persist longer in sediments than those with walls composed mostly of cellulose. Havinga found that in soils with high oxidation rates some pollen types (i.e., composites [Asteraceae], oak [*Quercus*], pine [*Pinus*], beech [*Fagus*], and basswood [*Tilia*]) persisted for longer periods of time than did other pollen types (i.e., hazelnut [*Corylus*], alder [*Alnus*], elm [*Ulmus*], poplar [*Populus*], maple [*Acer*], willow [*Salix*], and ash [*Fraxinus*]).

Other factors identified as causing damage to deposited pollen include soils with a high pH (Dimbleby 1957), high oxidation-reduction (Eh) values (Tschudy 1969), the microbial activity of certain species of soil fungi and bacteria (Goldstein 1960), and the cultural activities of humans including acts such as land modifications, fires, and plowing (Dimbleby 1985).

Another destructive agent appears to be the repeated cycles of soil hydration–dehydration. In a laboratory experiment, Holloway (1989) reported that cycles of wetting and drying caused significant changes and noticeable deterioration in the walls of pollen grains including crumpling, folding, and cracking. In his study, Holloway found that 76 percent of the 14 fresh pollen types he studied and 86 percent of the same 14 types that were acetolyzed (a chemical technique used to remove cytoplasm from pollen grains) showed various degrees of pollen wall destruction after 25 daily cycles of wetting and drying. The experiment also demonstrated how differential fossil-pollen preservation can occur. Of the 14 pollen types Holloway tested, those showing the greatest amount of pollen wall destruction by the end of 25 cycles were: pecan (*Carya*), juniper (*Juniperus*), cottonwood (*Populus*), Douglas fir (*Pseudotsuga*), willow (*Salix*), cattail (*Typha*), and maize (*Zea*). Other pollen types in the same experiment, such as marshelder (*Iva*) and amaranth (*Amaranthus*), generally showed only minor signs of degradation.

Holloway's (1989) experimental results confirm observations we have seen in the soils in archaeological sites. Sediments in rockshelters are often a good source of fossil pollen. However, at the Levi rockshelter in central Texas the sediments were barren of fossil pollen (Bryant 1969). Travertine deposits in portions of the rockshelter indicated that previous seepage, probably occurring over a long time period, created cycles of soil hydration–dehydration leading to the complete destruction of all fossil pollen.

The pollen recovered from archaeological site sediments represent the sum total of the originally deposited pollen *minus* the pollen lost to the processes of deterioration. If the percentage of pollen lost to destruction is not great, then the resulting pollen data will probably reflect an accurate representation of the original pollen taxa that were deposited. On the other hand, when too much of the originally deposited pollen is destroyed, the reliability of the remaining pollen is questionable. The difficult task is determining at what point during the preservation/destruction cycle of an archaeological site's pollen record do the data become unreliable.

In a study of Oklahoma and Texas rockshelters, Hall (1991) found that fossil-pollen concentrations declined dramatically with increasing depth and age of the deposits even though the rate of annual soil deposition was constant. He likens this progressive deterioration of fossil pollen to the concept of progressive decay (half-life) of radioactive isotopes. While some type of scale of progressive decay, or "half-life," may eventually be applied to pollen deterioration, for the present the concept remains untested except on the sediments of a few sites. At some future time it might be possible to develop a half-life scale for individual pollen taxa, for pollen buried in different types of sediments, and for archaeological sites located in different environmental settings.

We believe that the number of pollen types recovered, the percentages of indeterminable grains in a pollen sample, and the fossil-pollen concentration value are clues to the reliability of a pollen assemblage. In a study of 509 soil samples collected from a variety of late Holocene southwestern sites, Bryant et al. (1993) found that only 243 (48 percent) of the samples contained sufficient fossil pollen to conduct counts in excess of 200 grains. Of the remaining 266 samples (52 percent), most contained few pollen types, had high amounts of indeterminable pollen grains, and all had pollen-concentration levels below 1,000 pollen grains/cc of sediment.

The authors (Bryant et al. 1993) found an average of 7.5 pollen types in each of the 243 samples having sufficient pollen for counts of 200+ grains. The maximum number of taxa found in any of the fossil samples was 17. They also discovered that in each of the 243 samples the five most-frequent pollen types were: (1) pine; (2) cheno-ams (pollen types found in the family Chenopodiaceae and the genus *Amaranthus*); (3) composites (including both short- and long-spine types, sagebrush [*Artemisia*], and Liguliflorae types); (4) Mormon tea (*Ephedra*); and (5) grasses. Although these five pollen types represent plants commonly found in many southwestern plant communities, they also represent pollen types with distinctive morphological features that can be recognized even after the grains have been severely degraded.

The average fossil-pollen concentration value for each of the 243 samples was 6,545 pollen grains/cc of sediment; more than half of the 243 samples had fewer than 3,688 pollen grains/cc of sediment. In addition, the average number of indeterminable pollen per sample was 7.6 percent, with the highest percentages of indeterminable pollen coming from samples with the lowest pollen-concentration values.

As a comparative study, the same authors (Bryant et al. 1993) collected 89 surface samples from the same arid-type regions where the fossil samples were collected. Analysis of the 89 modern samples revealed that each contained an average of 17.4 different pollen types and had an average pollen-concentration value of 21,311 grains/cc of sediment.

This comparative study suggests that for some types of fossil samples, where acceptable pollen counts in excess of 200 fossil grains can be obtained, the interpretations based on those data may not be reliable. The data from the Bryant et al. (1993) study suggest that the fossil samples lost approximately 60 percent of their pollen types (17.4 − 7.5) and 70 percent of their total pollen (21,311 − 6,545) between the time the materials were first deposited and later recovered for analysis. This brings into serious question the validity of forming interpretations from fossil-pollen data when the resulting analyses are based on only 40 percent of the original pollen taxa and 30 percent of the originally deposited pollen.

To summarize, we believe that pollen data from archaeological sites should be suspect when they contain all three of the following: (1) fossil pollen from only a few plant taxa, especially when the most abundant pollen taxa are from the most durable types of pollen with very distinctive and easy-to-recognize morphological features; (2) when fossil-pollen concentration levels are below 1,000 grains/g or 2,500 grains/cc of sediment; and (3) when a sample contains a high percentage of indeterminable pollen grains.

RECOMMENDATIONS

Archaeological pollen studies are time consuming and require the talents of highly trained individuals. Extracting pollen from soil samples requires the use of highly toxic and dangerous chemicals, and the procedure can often take an entire day. Counting and interpreting pollen samples is also time consuming. For these reasons, we hope that others will understand why thorough pollen studies are costly to perform and why they require time to complete.

We encourage archaeologists to contact pollen analysts as far in advance as is possible so that sample processing, analysis, and report writing can be scheduled to meet existing deadlines. We also recommend that during the survey phase of an archaeological project a series of reconnaissance pollen samples, each from different strata or different sites, should be collected and evaluated for their fossil-pollen potential. This preliminary testing phase should focus on determining pollen-concentration levels and the degree of fossil-pollen preservation. If reconnaissance pollen tests reveal a good pollen recovery potential, then the archaeologist should be encouraged to incorporate additional pollen studies into the later site-excavation phase. Also, the archaeologist and pollen analyst should develop a fossil-pollen sample-collection plan. When possible, these plans should incorporate the advice of the project's geologist so that a well-dated and chronologically correct series of pollen samples can be examined. If, on the other hand, the results from all the reconnaissance samples reveal severe levels of fossil-pollen destruction, then the archaeologist must determine whether to continue testing new site or strata locations in hopes of finding new pollen-rich deposits, or abandon further attempts to recover fossil pollen. Unfortunately, as King et al. (1975) discovered from their studies of archaeological deposits in eastern North America, deposits at the same site location may contain ample fossil pollen for analyses in one location while nearby deposits will be nearly barren of fossil pollen.

Pollen information is not a panacea. It cannot always produce answers to the questions asked by archaeologists. Sometimes, soils are barren of fossil pollen, and analyses will produce nothing more than possible explanations why fossil pollen may no longer be present. In other cases, pollen data can provide meaningful insights about the cultural use of plants, prehistoric rituals involving the use of pollen, probable room use in pueblo-like structures, the functional use of artifacts, the presence of agriculture, and, under the right conditions, insights about paleovegetational sequences and inferences of climatic changes that cannot be obtained by other means.

Acknowledgments. We would like to thank John G. Jones, David L. Carlson, and Michael Waters for their suggestions during early drafts of this manuscript. We also appreciate the excellent comments provided to us by the reviewers selected by *American Antiquity* (Owen B. Davis, Suzanne K. Fish, and Richard G. Holloway).

REFERENCES CITED

Adams, D. P., and P. J. Mehringer
1975 Modern Pollen Surface Samples—An Analysis of Subsamples. *Journal of Research U.S. Geological Survey* 3:733–736.
Barkley, F. A.
1934 The Statistical Theory of Pollen Analysis. *Ecology* 47:439–447.
Bond, T.
1964 Removal of Colloidal Material from Palynological Preparations. *Oklahoma Geology Notes* 24:212–213.
Bryant, V. M., Jr.
1969 *Late Full-Glacial and Post-Glacial Pollen Analysis of Texas Sediments.* Unpublished Ph.D. dissertation, Department of Botany, University of Texas, Austin.
1988 Preservation of Biological Remains from Archaeological Sites. In *Interdisciplinary Workshop on the Physical–Chemical–Biological Processes Affecting Archaeological Sites,* edited by C. Mathewson, pp. 85–115. U.S. Army Corp of Engineers Waterways Experiment Station, Vicksburg, Mississippi.
Bryant, V. M., Jr., and R. G. Holloway
1983 The Role of Palynology in Archaeology. In *Advances in Archaeological Method and Theory,* vol. 6, edited by M. B. Schiffer, pp. 191–224. Academic Press, New York.
Bryant, V. M., Jr., and D. P. Morris
1986 Uses of Ceramic Vessels and Grinding Implements: The Pollen Evidence. In *Archeological Investigations at Antelope House,* by D. P. Morris, pp. 489–500. Publications in Archeology No. 19. National Park Service, Washington, D.C.
Bryant, V. M., Jr., and J. Schoenwetter
1987 Pollen Records from Lubbock Lake. In *Lubbock Lake, Late Quaternary Studies on the Southern High Plains,* edited by E. Johnson, pp. 6–40. Texas A&M University Press, College Station.
Bryant, V. M., Jr., and G. H. Weir
1986 Pollen Analysis of Floor Sediment Samples: A Guide to Room Use. In *Archeological Investigations at Antelope House,* by D. P. Morris, pp. 58–71. Publications in Archeology No. 19. National Park Service, Washington, D.C.
Bryant, V. M., Jr., R. G. Holloway, J. G. Jones, and D. L. Carlson
1993 Pollen Preservation in Alkaline Soils of the American Southwest. In *Sedimentation of Organic Particles,* edited by A. Traverse. Cambridge University Press, Cambridge, in press.
Clary, K. H.
1989 Reducing Ambiguity in the Archaeological Pollen Record by Improving Recovery of Economic Pollen. (Abstracts of the Proceedings of the Twenty-First Annual Meeting of the American Association of Stratigraphic Palynologists.) *Palynology* 13:281.
Clisby, K. H., and P. B. Sears
1956 San Augustine Plains–Pleistocene Climatic Changes. *Science* 124:537–539.

Dean, G.
1991 *Archaeobotanical Analysis of Pollen and Phytolith Samples from Prehistoric Structural and Agricultural Features at LA 2742, LA 70577, LA 71189, and LA 71190, Pot Creek Project, Taos County, New Mexico.* Technical report No. 303. Castetter Laboratory for Ethnobotanical Studies, Albuquerque.
Dimbleby, G. W.
1957 Pollen Analysis of Terrestrial Soils. *New Phytologist* 56:12–28.
1985 *The Palynology of Archaeological Sites.* Academic Press, New York.
Duhoux, E.
1982 Mechanism of Exine Rupture in Hydrated Taxoid Type of Pollen. *Grana* 21:1–7.
Faegri, K., P. E. Kaland, and K. Krzywinski
1989 *Textbook of Pollen Analysis.* 4th ed. Hafner, New York.
Gish, J.
1993 Large Fraction Pollen Scanning and Its Application in Archaeology. In *Archaeological Palynology,* edited by O. Davis. American Association of Stratigraphic Palynologists Contribution Series, Dallas, in press.
Goldstein, S.
1960 Degradation of Pollen by Phycomycetes. *Ecology* 41:543–545.
Gray, J.
1961 Extraction Techniques. In *Handbook of Paleontological Techniques,* edited by B. Kummel and D. Raup, pp. 530–587. Freeman, San Francisco.
Hall, S. A.
1981 Deteriorated Pollen Grains and the Interpretation of Quaternary Pollen Diagrams. *Review of Paleobotany and Palynology* 32:193–206.
1985 Bibliography of Quaternary Palynology in Arizona, Colorado, New Mexico and Utah. In *Pollen Records of Late-Quaternary North American Sediments,* edited by V. M. Bryant, Jr., and R. G. Holloway, pp. 407–423. American Association of Stratigraphic Palynologists Foundation, Dallas.
1991 Progressive Deterioration of Pollen Grains in South-Central U.S. Rockshelters. *Journal of Palynology* (1990–1991):159–164.
Havinga, A. J.
1964 Investigations into the Differential Corrosion Susceptibility of Pollen and Spores. *Pollen et Spores* 6: 621–635.
1984 A 20-Year Experimental Investigation into the Differential Corrosion Susceptibility of Pollen and Spores in Various Soil Types. *Pollen et Spores* 26:541–558.
Hill, J., and R. Hevly
1968 Pollen at Broken K Pueblo: Some New Interpretations. *American Antiquity* 33:200–210.
Holloway, R. G.
1981 *Preservation and Experimental Digenesis of the Pollen Exine.* Unpublished Ph.D. Dissertation, Department of Biology, Texas A&M University, College Station.
1989 Experimental Mechanical Pollen Degradation and Its Application to Quaternary Age Deposits. *Texas Journal of Science* 41:131-145.
Horowitz, A., R. E. Gerald, and M. S. Chaiffetz
1981 Preliminary Paleoenvironmental Implications of Pollen Analyzed from Archaic, Formative, and Historical Sites Near El Paso, Texas. *Texas Journal of Science* 33:61–72.
King, J. E., W. E. Klippel, and R. Duffield
1975 Pollen Preservation and Archaeology in Eastern North America. *American Antiquity* 40:180–190.
Lennie, C.
1968 Palynological Techniques Used in New Zealand. *New Zealand Journal of Geology and Geophysics* 11: 1211–1221.
Martin, P. S.
1963 *The Last 10,000 Years: A Fossil Pollen Record of the American Southwest.* University of Arizona Press, Tucson.
Moore, P., J. Webb, and M. Collinson
1991 *Pollen Analysis.* 2nd ed. Blackwell Scientific Publications, Boston.
Morris, D. P.
1986 *Archeological Investigations at Antelope House.* Publications in Archeology No. 19. National Park Service, Washington, D.C.
Pearsall, D. M.
1989 *Paleoethnobotany: A Handbook of Procedures.* Academic Press, New York.
Phipps, D., and G. Playford
1984 Laboratory Techniques for Extraction of Palynomorphs from Sediments. *Papers of the Department of Geology of the University of Queensland* 11:1–23.
Sears, P. B.
1932 The Archaeology of Environment in Eastern North America. *American Anthropologist* 34:610–622.
1937 Pollen Analysis as an Aid in Dating Cultural Deposits in the United States. In *Early Man,* edited by G. MacCurdy, pp. 61–66. Lippincott, London.

Sears, P. B., and K. H. Clisby
1952 Two Long Climatic Records. *Science* 116:176–178.
Shafer, H., and R. Holloway
1979 Organic Residue Analysis in Determining Stone Tool Function. In *Lithic Use-Wear Analysis*, edited by B. Hayden, pp. 385–399. Academic Press, New York.
Stockmarr, J.
1971 Tablets with Spores Used in Absolute Pollen Analysis. *Pollen et Spores* 13:615–621.
Sobolik, K. D.
1988 The Importance of Pollen Concentration Values from Coprolites: An Analysis of Southwest Texas Samples. *Palynology* 12:201–214.
Traverse, A.
1989 *Paleopalynology*. Unwin Hyman, Boston.
Tschudy, R.
1969 Relationship of Palynomorphs to Sedimentation. In *Aspects of Palynology*, edited by R. Tschudy and R. Scott, pp. 79–96. John Wiley and Sons, New York.
Williams-Dean, G.
1986 Pollen Analysis of Human Coprolites. In *Archeological Investigations at Antelope House*, by D. P. Morris, pp. 189–205. Publications in Archeology No. 19. National Park Service, Washington, D.C.

Received December 13, 1991; accepted February 15, 1993

GRINDING-TOOL DESIGN AS CONDITIONED BY LAND-USE PATTERN

Margaret C. Nelson and Heidi Lippmeier

The form in which archaeologists recover artifacts is the product of intentional design, use modification, and postdepositional alteration. Analysis of grinding tools, from small prehistoric sites in southwestern New Mexico, indicates the effects of intentional design and use modification on artifact form. These variables of technological behavior are considered in relation to anticipated, regular occupation of sites. Distinguishing the extent to which site visits are anticipated and regular can enhance our understanding of how places and resources were used and how land use was organized. Because grinding tools commonly remain on sites, their anticipated reuse signals anticipated reuse of the places where they occur. While characteristics of intentional design positively correlate with regularity of site occupation, the effects of use modification do not.

La morfología de los artefactos recuperados por arqueólogos es el producto de diseño intencional, modificación de uso y alteraciones occurridas después de que los artefactos fueron depositados. El análisis de piedras para moler provenientes de pequeños sitios prehistóricos en el sudoeste de Nuevo México indica los efectos del diseño intencional y modificacíon de uso en la morfología de los artefactos. Estas variables de conducta tecnológica son examinadas en relación a la ocupación regular y anticipada de los sitios. Al entender hasta qué punto las visitas a los sitios eran anticipadas y regulares podremos aumentar nuestro conocimiento acerca de la manera como los sitios y los recursos fueron usados y de cómo el uso de la tierra estaba organizado. Puesto que las herramientas para moler son generalmente dejadas en los sitios en vez de ser transportadas de un lugar a otro, su reuso anticipado indica el reuso anticipado de los sitios en los cuales dichas herramientas son halladas. Se ha encontrado una correlación positiva entre las características de diseño intencional y la regularidad de ocupación de sitios. Sin embargo tal correlacción no existe entre este último factor y los efectos de modificación de uso.

Artifact form is the product of numerous, complex influences. The most fundamental condition influencing tool design is the task for which a tool is expected to be used; all tools must be minimally

Margaret C. Nelson, Department of Anthropology, State University of New York, Buffalo, NY 14261
Heidi Lippmeier, Department of Anthropology, State University of New York, Buffalo, NY 14261

American Antiquity, 58(2), 1993, pp. 286–305.